STUDIES ON TRANSPLANTATION IN *PLANARIA*.

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During the last two years, the writer has been engaged in a study of transplantation in *Planaria*. The present paper is a brief statement of some of the more important results obtained thus far.

The work was undertaken in the hope of throwing light on various questions. For example: may a grafted piece act as an "organizer" or "reorganizer"? Is its effect species-specific? On what factors does the fate of the graft depend?

MATERIALS AND METHODS.

Planaria dorotocephala Woodworth, and *Planaria maculata* Leidy were the animals used in the work herein reported. The size of the worms used ranges from ten to twenty-two millimeters in length. A weak aqueous solution of chloretone (ca. M/100) was used, in most cases as anaesthetic. The donors were not anaesthetized. In some cases neither the host nor the donor was anaesthetized. In some of the experiments, a triangular hole was made through the body of the host by means of a sharp scalpel at the desired level of the body and a triangular piece of about the same size as the hole from a certain level of the body of the donor was inserted into the hole by means of a capillary pipet, while in other series of experiments a circular hole was made by means of a sharp capillary pipet. The advantage of using triangular pieces and triangular holes in this experiment is very obvious, in as much as the polarity of the graft and of the host was one of the points under investigation. The operated worms were kept in the dark in moist chambers consisting of fingerbowls and small watch glasses with very little well-water, only enough to keep the worms moist, for about twelve to twenty-four hours immediately following the operation. After this length of time,

those with successful grafts were examined under a binocular microscope; counted, recorded and transferred into fingerbowls with ca. 200 cc. fresh well-water, covered with glass plates and kept in the dark in the usual way. In some of the experiments, the host was beheaded to keep it relatively quiet and thus increase the per cent. of "takes," while in other cases, the host was not beheaded. Both homoioplastic transplantation and heteroplastic transplantation were performed the latter between *Planaria dorotocephala* and *Planaria maculata*. In some of the experiments *P. maculata* was the host, while in others the host was *Planaria dorotocephala*. Head, prepharyngeal, pharyngeal, postpharyngeal, and tail regions were the different levels of the body that have been used both as graft and as region of insertion in these experiments. The grafted piece was either transplanted without its axis being rotated, or the axis of the transplanted piece was rotated 60–180 degrees, and in some cases, the piece was grafted with its dorsal surface toward the ventral surface of the host. Histological studies of the results are being made and will be reported elsewhere.

Experiments and Results.

Portions of the head (Figs. 1, 2, 3) of *Planaria dorotocephala* similar to those used as head grafts were isolated. Result: As a rule, these isolated portions of the head, if not too small, remained alive for several days or longer but did not reconstitute postcephalic region (Figs. 4, 5).

When a piece of the ganglionic region of the head above certain size (Figs. 1, 2, 3) is transplanted into the prepharyngeal region very near the head of the host, it reconstitutes a head of some sort which may later be resorbed, or may become detached, or in case the host is beheaded for the second time, it may develop as in Figs. 6, 7, and 8, with very little or no outgrowth from the host tissue. And if the host is beheaded for the second or third time after transplantation, the grafted head usually decreases the head frequency of the host. If the cut in the second or third beheading is very close to the region of the graft, head formation at the cut surface may be completely inhibited; and in this case, the grafted head acts as the head of the host (Fig. 9). If the inhibition of head formation at the cut surface at the third beheading

is not complete, the two heads may approach each other and sooner or later fuse together (Fig. 10).

A piece of the ganglionic region of the head (Figs. 1, 2, 3), if not too small, when transplanted into the prepharyngeal region, is not resorbed, but is capable of reconstituting a complete head and of inducing the development of an outgrowth (Figs. 11–15), and thus a new axis is formed with the grafted piece at its tip.

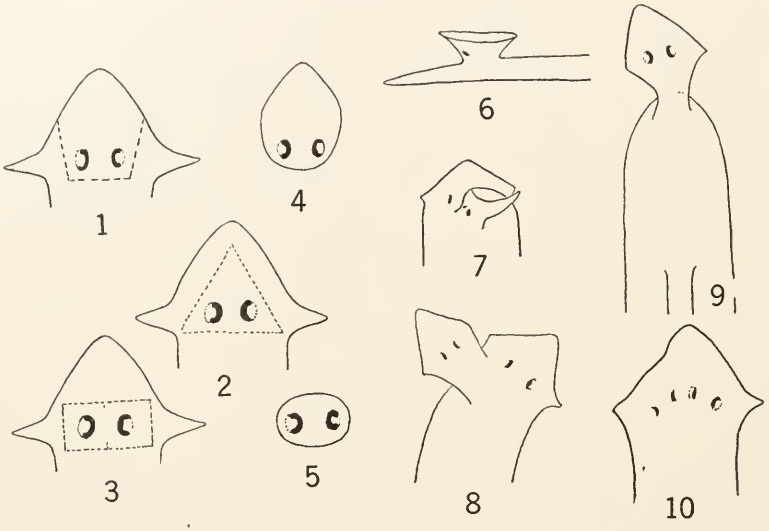


Fig. 1. Head of *Planaria* showing the part transplanted.
Fig. 2. Head of *Planaria* showing the part transplanted.
Fig. 3. Head of *Planaria* showing the part transplanted.
Fig. 4. Isolated portion of the head of *Planaria dorotocephala*, 12 days after isolation.
Fig. 5. Isolated portion of the head of *Planaria dorotocephala*, 12 days after isolation.
Fig. 6. Side view of *Planaria dorotocephala* with headgraft.
Fig. 7. *Planaria dorotocephala* with head-graft.
Fig. 8. *Planaria dorotocephala* with head-graft.
Fig. 9. *Planaria dorotocephala* with head-graft from *P. maculata*.
Fig. 10. *Planaria dorotocephala* with grafted head from *P. dorotocephala* fused with the regenerated head of the host, after the third beheading.

A piece of the ganglionic region of the head transplanted to a region very near the head of the host does not act as an organizer. When transplanted to more posterior regions, if not resorbed, it acts as an organizer. When transplanted into the postpharyngeal region near the tail, if not resorbed, it is capable of inducing the

formation of a secondary pharynx in the posterior region, and of reversing the polarity of the region originally anterior to the level of the graft. This reversal of polarity is shown by the development of a new pharynx opposite in direction to the original pharynx and by complete reorganization of the alimentary tract. It may also inhibit head formation at the cut surface several millimeters

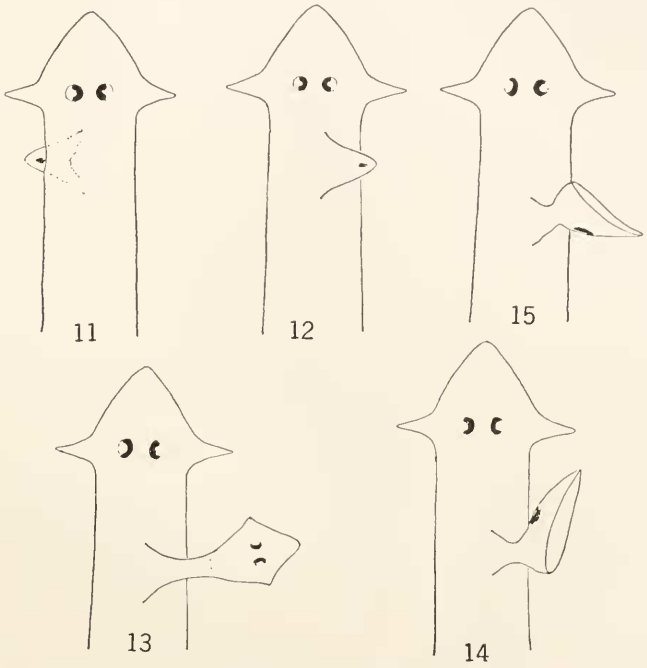


FIG. 11. *P. dorotocephala* with head-graft developing on the ventral surface of the host. Graft is partly inhibited.

FIG. 12. *P. dorotocephala* with head-graft developing on the dorsal surface of the host. Graft is partly inhibited.

FIG. 13. *P. maculata* with head-graft from *P. dorotocephala.*

FIG. 14. *P. maculata* with head-graft from *P. dorotocephala.*

FIG. 15. *P. maculata* with head-graft from *P. dorotocephala.*

anterior to the graft after the anterior part of the host is removed for the second, third or fourth time, posterior or through the pharynx. The result in these cases apparently depends upon the physiological activity of the level of the body of the host and of

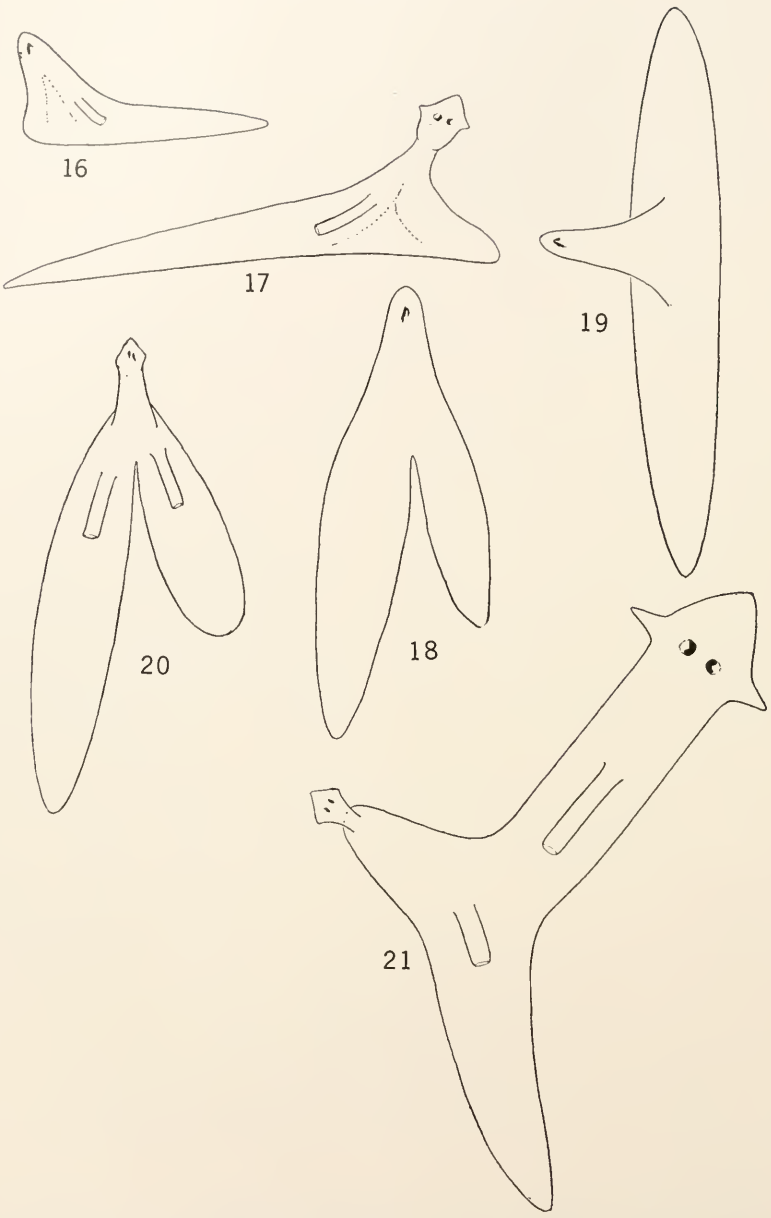
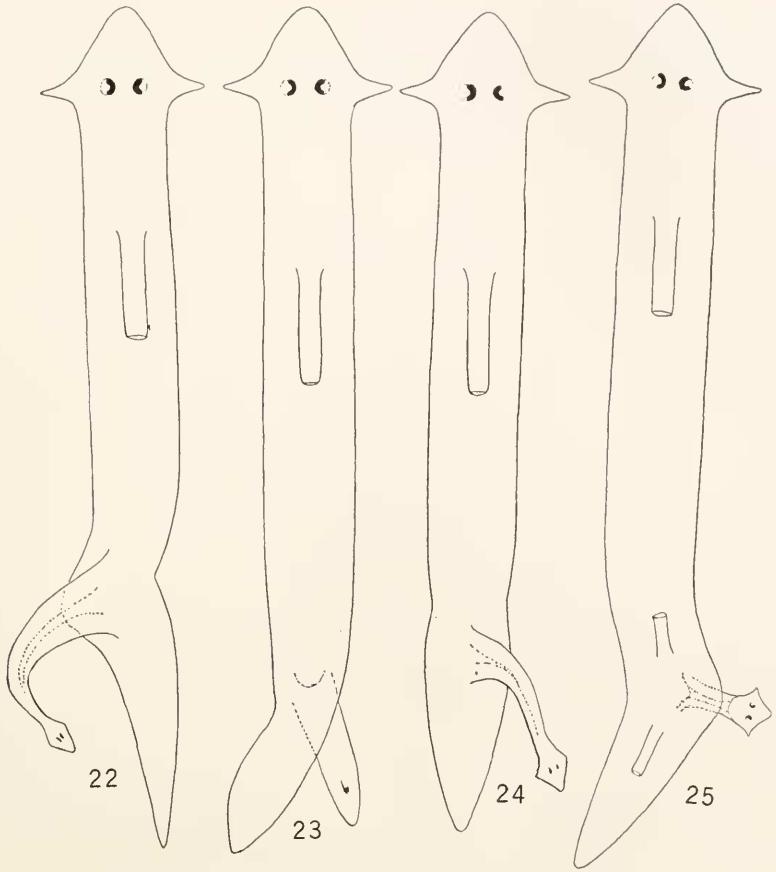


Fig. 16. *P. dorotocephala* with postpharyngeal head-graft from *P. dorotocephala*. Side view showing the induced pharynx.

Fig. 17. *P. dorotocephala* with postpharyngeal head-graft from *P. dorotocephala*. Side view showing the induced pharynx.

Fig. 18. *P. dorotocephcla* with postpharyngeal head-graft from P. *doro-*



tocephala. Regeneration of head at the anterior cut surface is prevented, and showing reversal of polarity.

FIG. 19. *P. dorotocephala* with postpharyngeal head-graft from *P. dorotocephala.* Regeneration of head at the anterior cut surface is prevented, and showing reversal of polarity.

FIG. 20. *P. dorotocephala* with postpharyngeal head-graft from *P. dorotocephala.* Regeneration of head at the anterior cut surface is prevented, and showing induced secondary pharynges and reversal of polarity.

FIG. 21. *P. maculata* with postpharyngeal head-graft from *P. dorotocephala.* Showing the induced secondary pharynx.

FIG. 22. *P. dorotocephala* with postpharyngeal head-graft from *P. dorotocephala,* showing the induced outgrowth from host tissue.

FIG. 23. *P. dorotocephala* with postpharyngeal head-graft from *P. maculata.*

FIG. 24. *P. dorotocephala* with postpharyngeal head-graft from *P. maculata.*

FIG. 25. *P. maculata* with postpharyngeal head-graft from *P. maculata,* showing the two induced pharynges and reversal of polarity.

the grafted head and of the species used as host. Cross transplantation between *Planaria maculata* and *P. dorotocephala* shows that this capacity to reverse the polarity and to induce the development of secondary pharynges in the posterior region of the host is not species-specific, for the head of *P. dorotocephala* is capable of

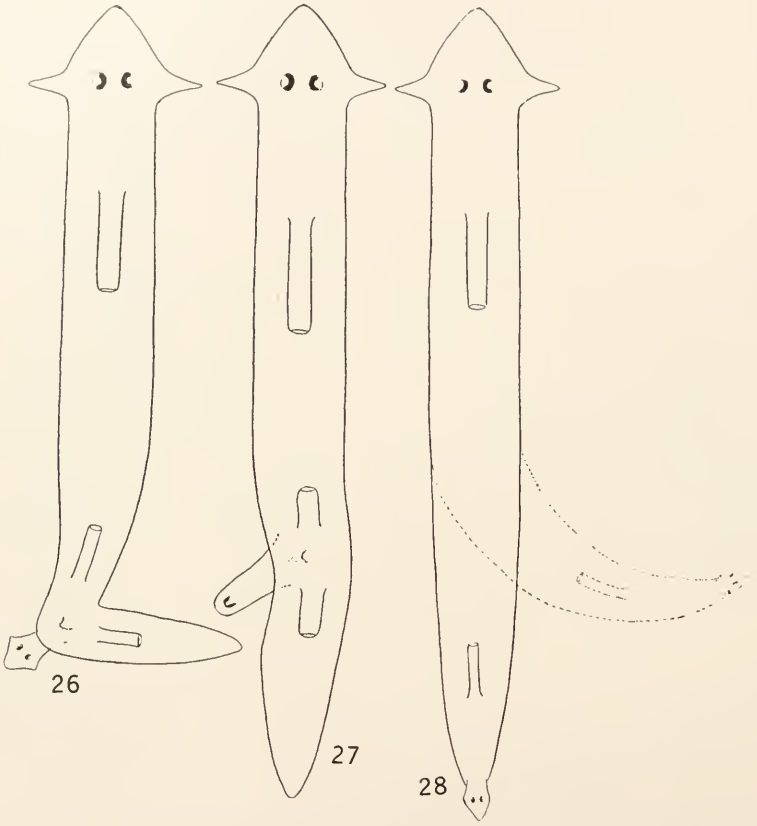


FIG. 26. *P. dorotocephala* with postpharyngeal head-graft from *P. maculata*, showing the induced pharynges and reversal of polarity.

FIG. 27. *P. maculata* with head-graft from *P. maculata*, showing the induced secondary pharynges and reversal of polarity.

FIG. 28. *P. dorotocephala* with head-graft from *P. maculata*, showing the induced pharynx and reversal of polarity.

inhibiting head formation at the cut surface several millimeters anterior to it, reversing the polarity of the region anterior to it, and inducing the formation of secondary pharynges (Figs. 16–31)

in *P. maculata* as host and vice versa. Feeding experiments show that these secondary pharynges induced by the grafted head, are functional, *i.e.,* they are extruded and attached to the piece of liver and show the normal peristalsis of the pharynx characteristic of the feeding reaction of *Planaria.*

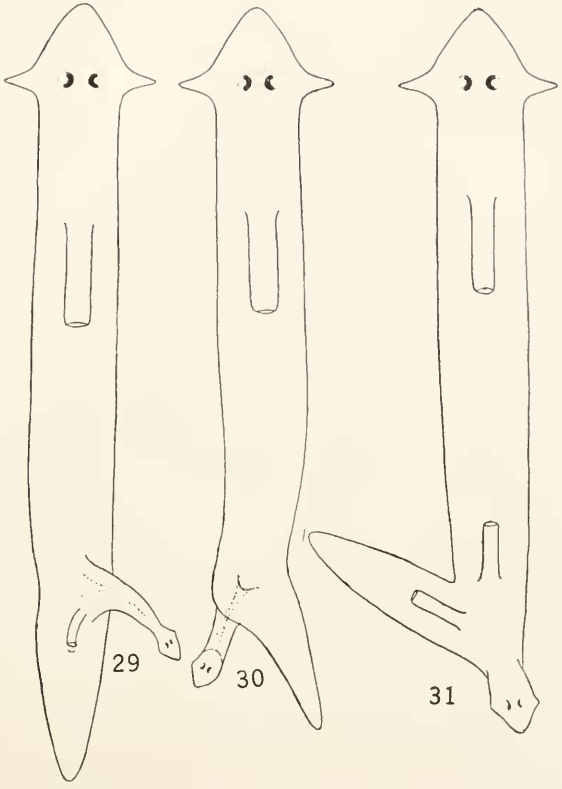


FIG. 29. *P. dorotocephala* with head-graft from *P. maculata,* showing the induced secondary pharynx and outgrowth from host tissue.

FIG. 30. *P. dorotocephala* with head-graft from *P. dorotocephala,* showing outgrowth from host tissue.

FIG. 31. *P. dorotocephala* with head-graft from *P. dorotocephala,* showing induced secondary pharynges and reversal of polarity.

Discussion.

Considering the results of all the experiments performed not merely of those herein reported, the writer is of the opinion that the fate of the graft does not depend primarily upon its degree of specialization, but rather upon the degree of physiological activity of the graft, and of the region of the host into which the piece is implanted, *i.e.,* if the degree of physiological activity of the graft is very high with respect to the region of the host where it is grafted, the graft may not be resorbed, particularly when it is far from the dominant region of the host. For example, when a portion of the head (an example of a piece of the body with a very high degree of physiological activity) is transplanted into a region very near the head of the host, the activity of the grafted head may be decreased by the dominant head of the host and it may finally be resorbed, or else fusion of the two heads may take place.

In *Planaria,* the head is the most active and hence the most dominant region of the body. This fact has been experimentally demonstrated, qualitatively and quantitatively, by Child and confirmed by others in different species of animals besides *Planaria dorotocephala.* Rand and Ellis (1926) working on *P. maculata,* had confirmed the dominance of the head. They termed it "inhibitory dominance." Rand and Browne (1926) working on *P. maculata* had demonstrated that the presence of a grafted head may inhibit the regeneration of a head at an exposed anterior cut surface. The results of some of the experiments herein reported confirm this finding of Rand and Browne.

The head of some sort developed from a graft consisting of a portion of the ganglionic region may not only inhibit the development of a head at a cut surface some distance anterior to it, but may completely reverse the polarity of a region anterior to its level and may induce the reorganization of a region posterior to its level with the formation of a secondary pharynx. Evidently the graft from the ganglionic region is able to act as an "organizer" or more strictly speaking, as a "reorganizer" (Child, 1929) of other regions of the body into which it is implanted.

Grafts of other regions of the body may in some cases give rise to outgrowths. Whether or not such outgrowth develop in particular cases depends on various factors, *e.g.*, size and orientation of graft, level from which it is taken and region into which it is implanted. Further investigation is necessary, however, to determine to what extent a real reorganization occurs in such outgrowths.

Summary.

1. A new technique of transplantation in *Planaria* which gives a high per cent. of "takes" is described.

2. The head, or part of it, which is the most active region of the body of *Planaria,* when transplanted into the postpharyngeal region or relatively less active region of the body, is capable, not only of acting as an organizer, and completely reversing the polarity of the region anterior to it, but also inhibiting the formation of a head at a cut surface several millimeters anterior to it.

3. Both homoioplastic and heteroplastic transplantations were performed in *Planaria dorotocephala* and *P. maculata.* The results of the experiments on heteroplastic transplantation between the two species used, show that the action of the graft is not species-specific.

4. The results of the experiments indicate that the fate of the graft does not depend primarily upon the degree of its specialization but on the degree of physiological activity of the level of the body from which it is taken and also on the region of the body of the host in which it is implanted.

5. The fate of the graft also depends upon the size of the graft, degree of "take," and orientation of the graft in the body of the host.

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